Pulsars, Cosmology, and Science with Giant Telescopes

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CCS-3

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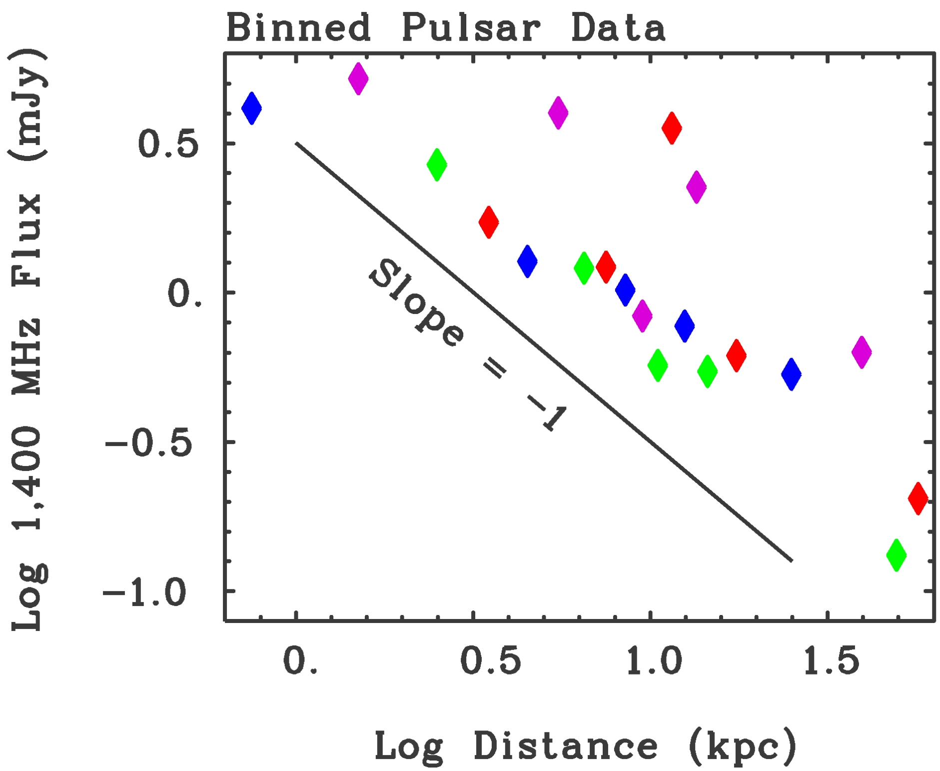
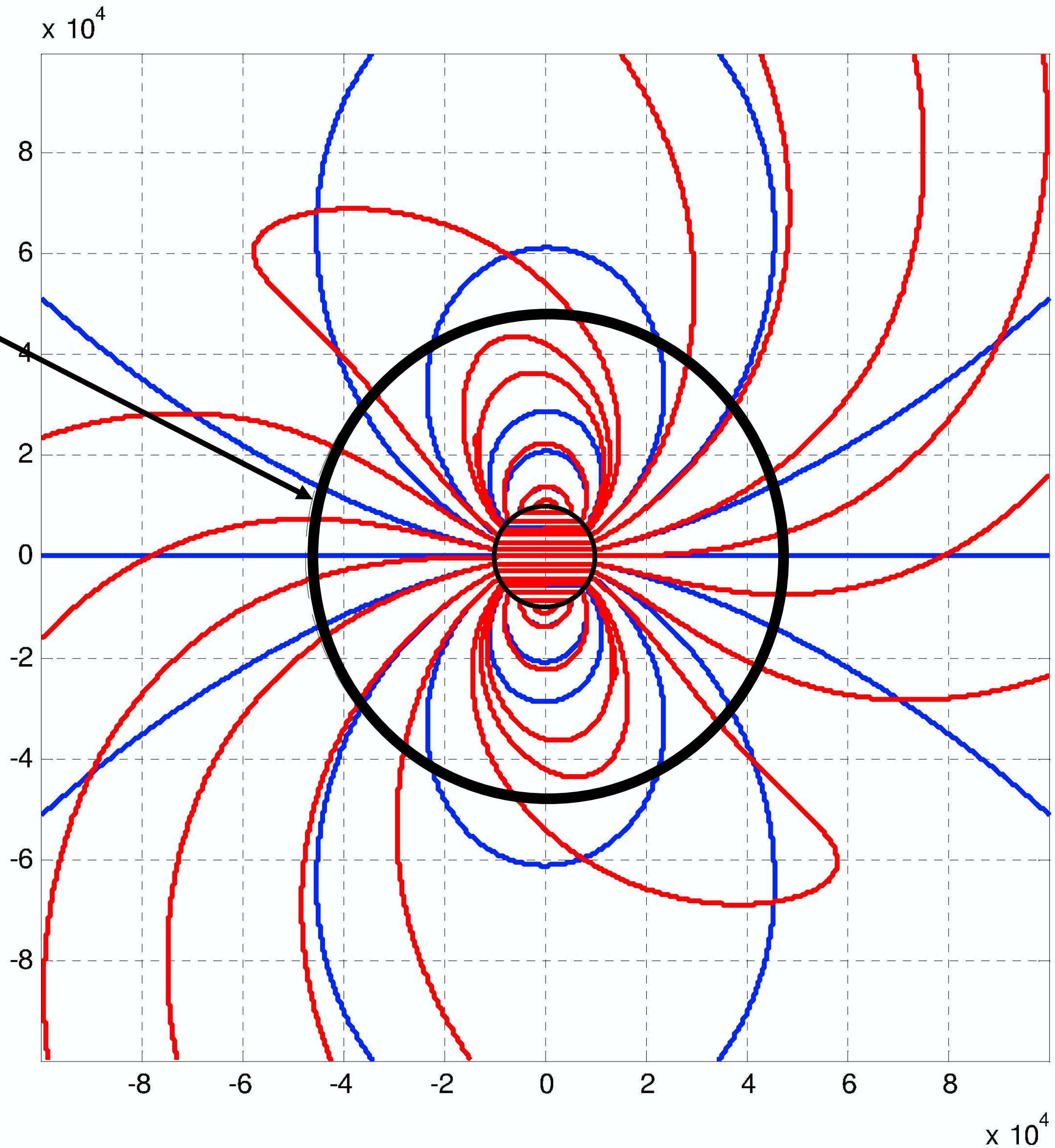
Pulsars Dim only as 1/distance:

- This remarkable fact was *predicted* in H. Ardavan's Superluminal Polarization Current Model (SLP -- H. Ardavan, 1998, Phys. Rev. E., 58, 6659, and later references).
- We know how to survey.
- We know how long to look.
- We know when to quit.
- But we don't have to survey, because there's a free lunch! (More below.)

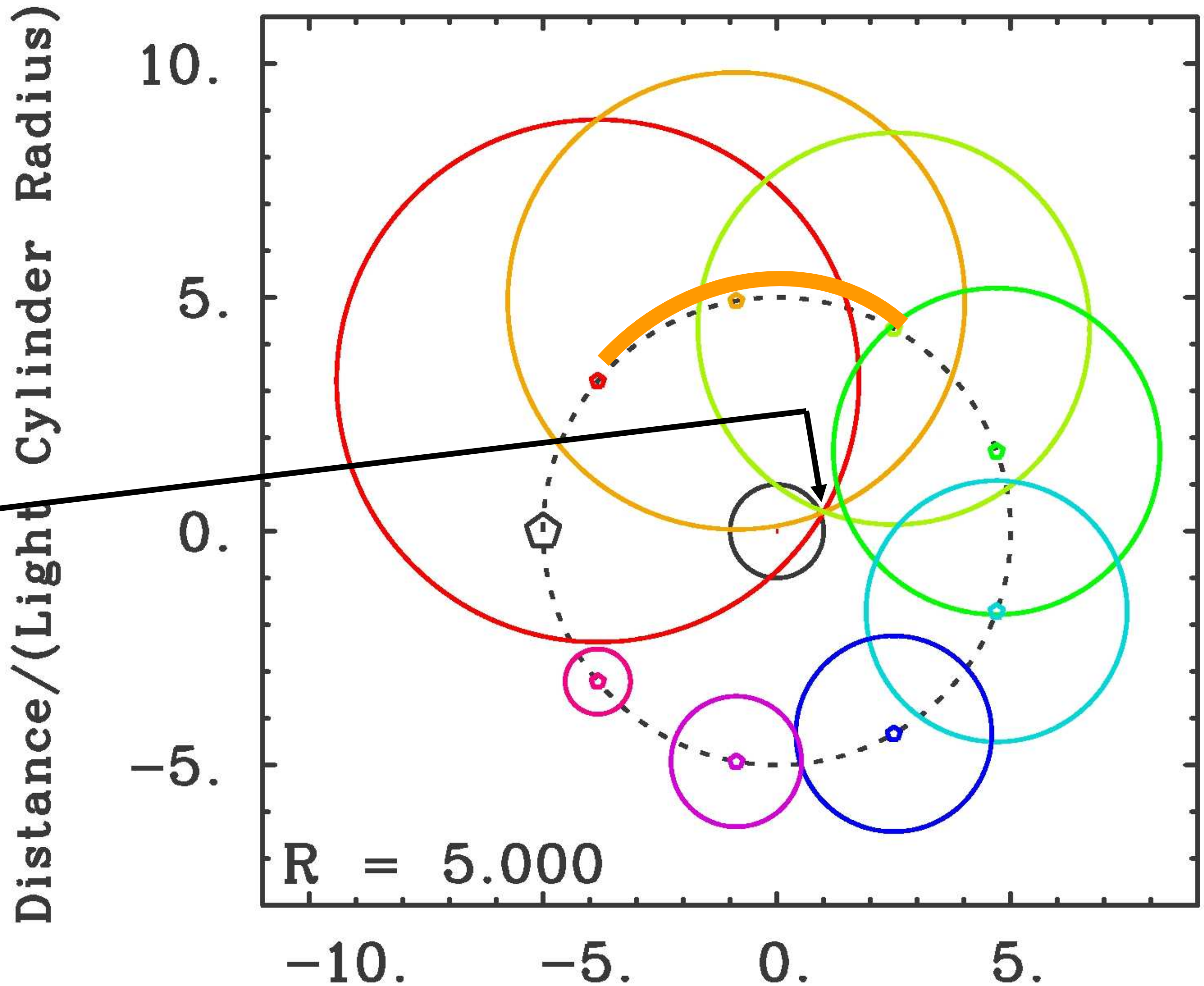


Polarization currents outside the light cylinder are induced by the electric field produced by the rotating magnetic field. These currents are updated faster than the speed of light.

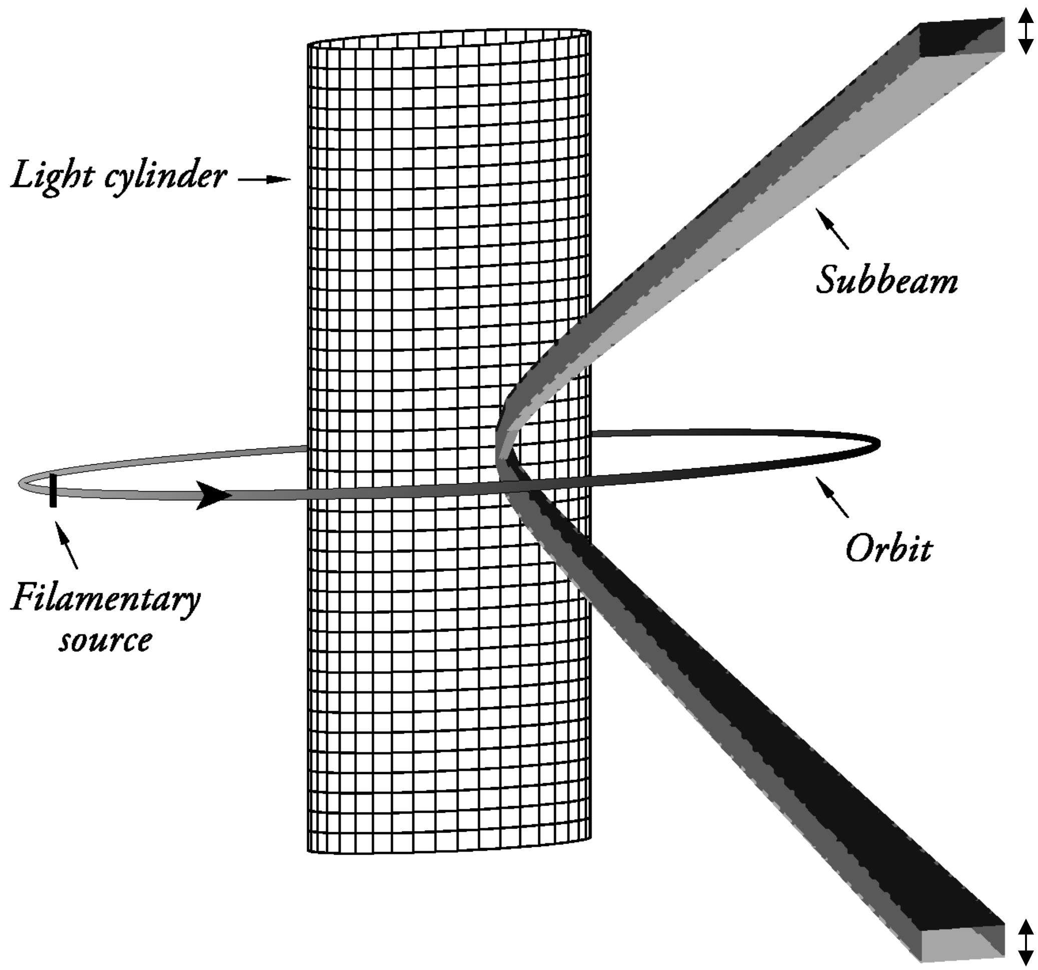


(Blue – non-rotating. Red – rotating clockwise.)

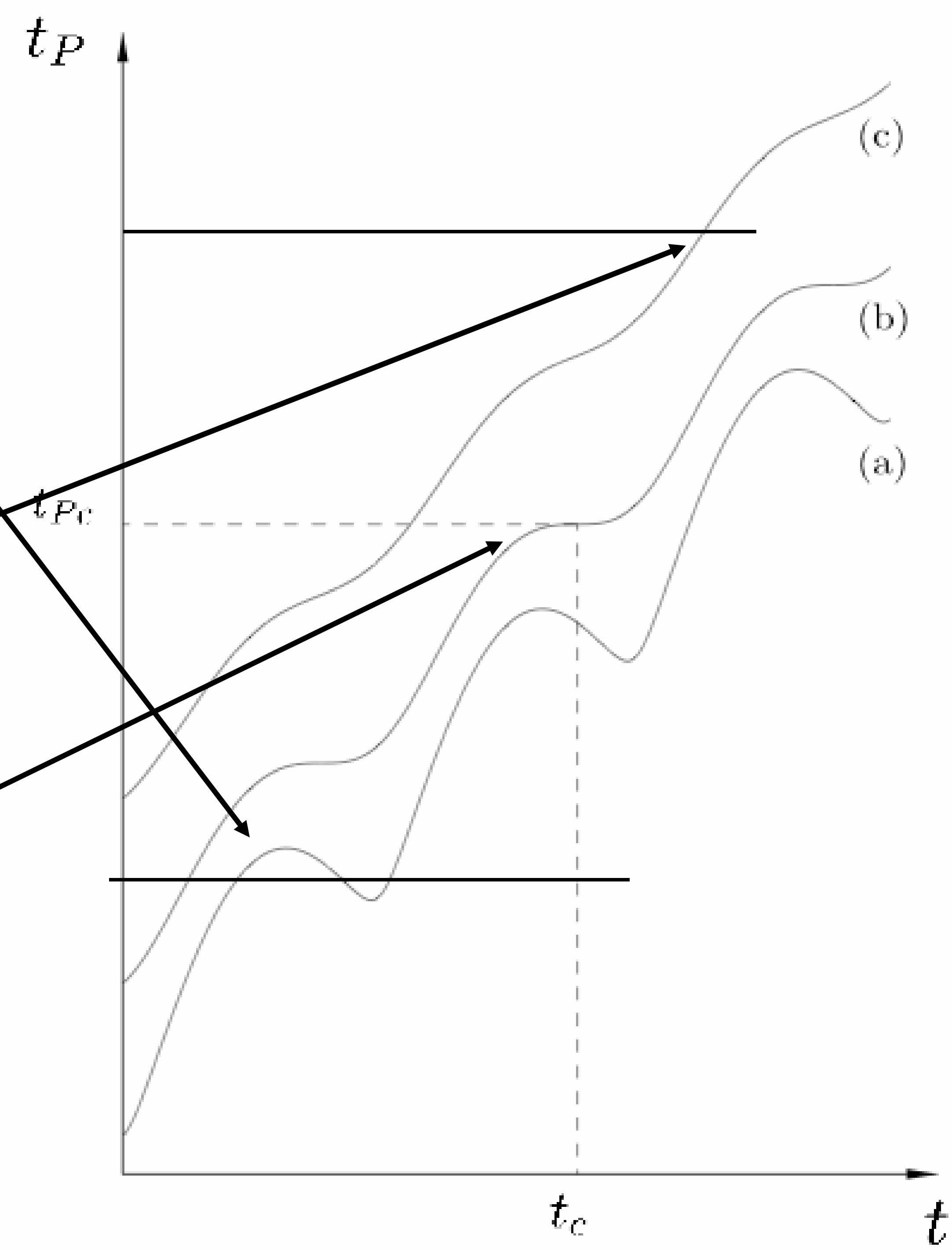
With a source orbiting at 5xLC radius, the emission in its history, from 10 hr 20 m to 1 o'clock, all contribute to a spot tangent to the LC near 2 o'clock.



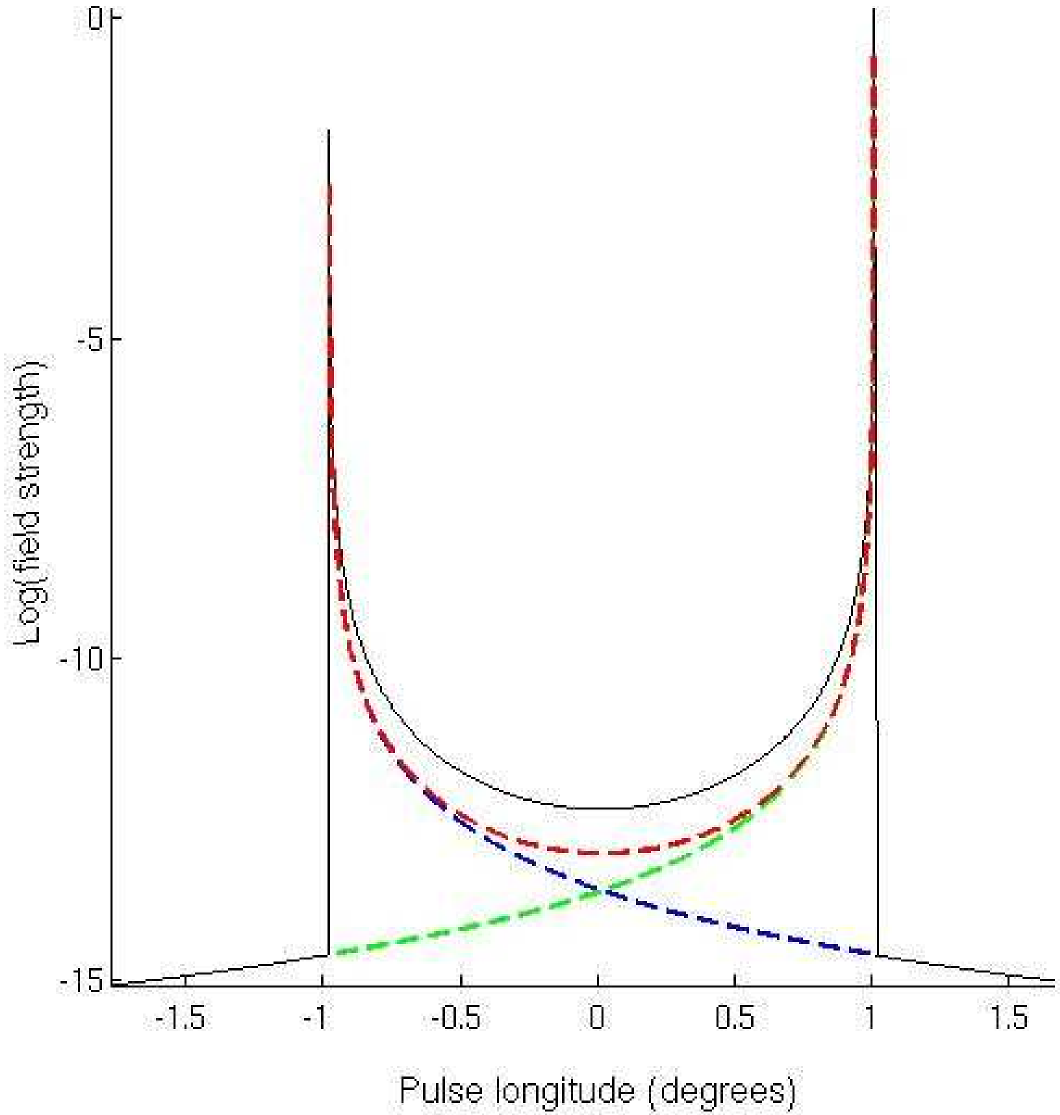
How does the 1/distance relation happen? A subbeam has a constant height in the polar direction, and thus the flux drops only as 1/distance. The pulsar angular beam width does not necessarily diminish at great distances because there are many, many subbeams.



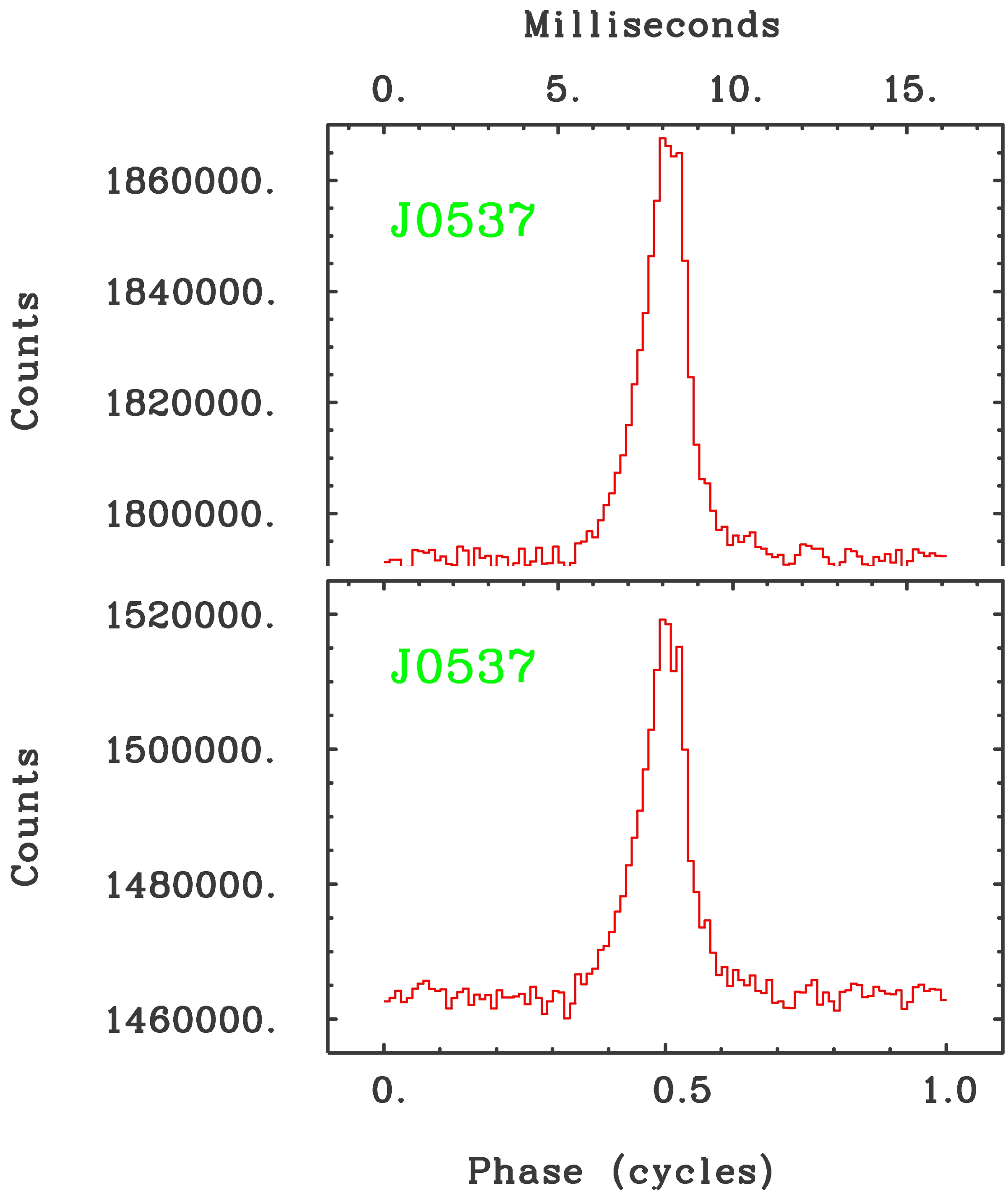
Typically, contributions from 3 sources contribute to what is seen by the observer (curve ‘a’), but for certain geometries, only one source (curve ‘c’), or for others (such as our example two viewgraphs back), an infinite number (curve ‘b’ for observer time t_{Pc}).



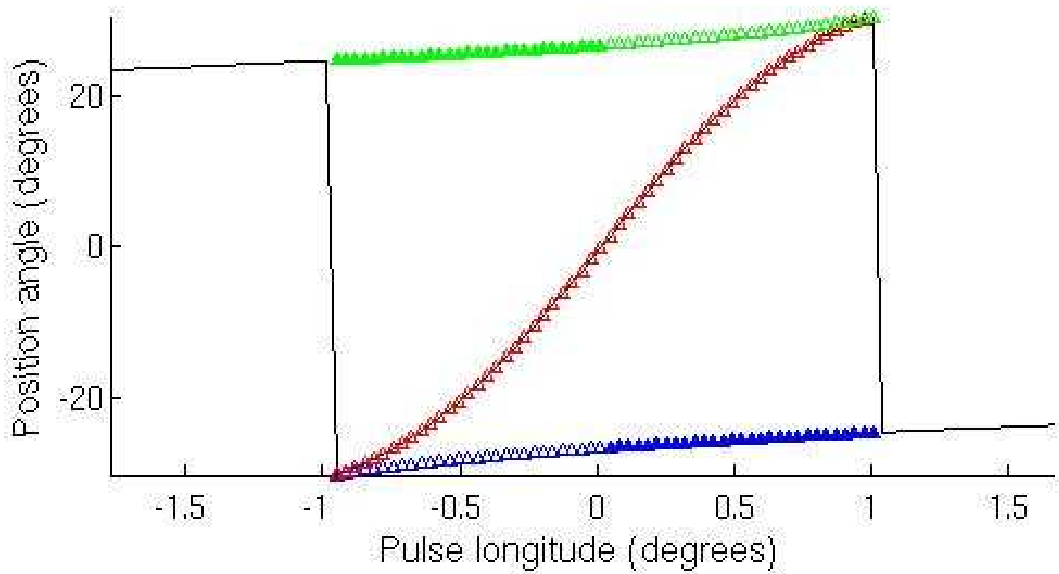
In the SLP model, the pulse profile comes from the same 3 sources. These produce the typical, cusped, doubly-peaked profile, and predict that all singly-pulsed profiles are actually doubles.

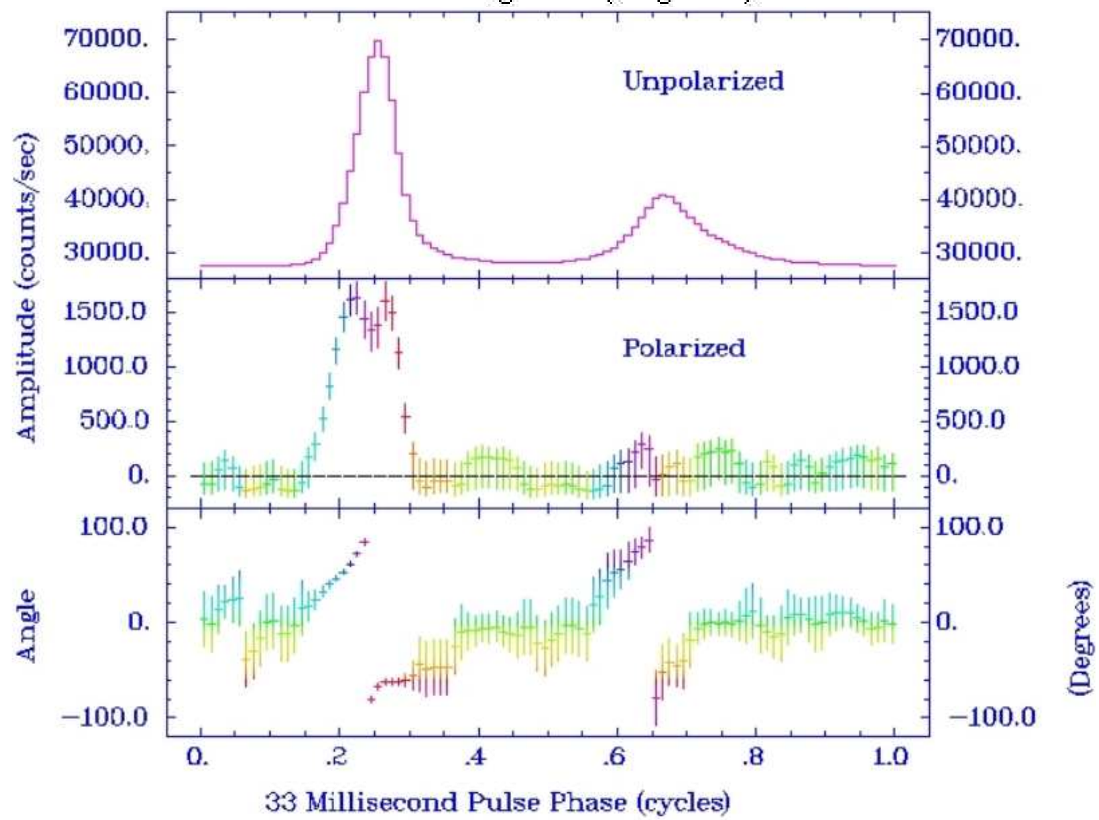


The pulse profile of PSR J0537-6910 (16.1 ms) tends to progressively split, if allowed, over successive iterations which generate a new master fitting pulse each time, consistent with the prediction of the SLP model. Proving this is meaningful will be the hard part.

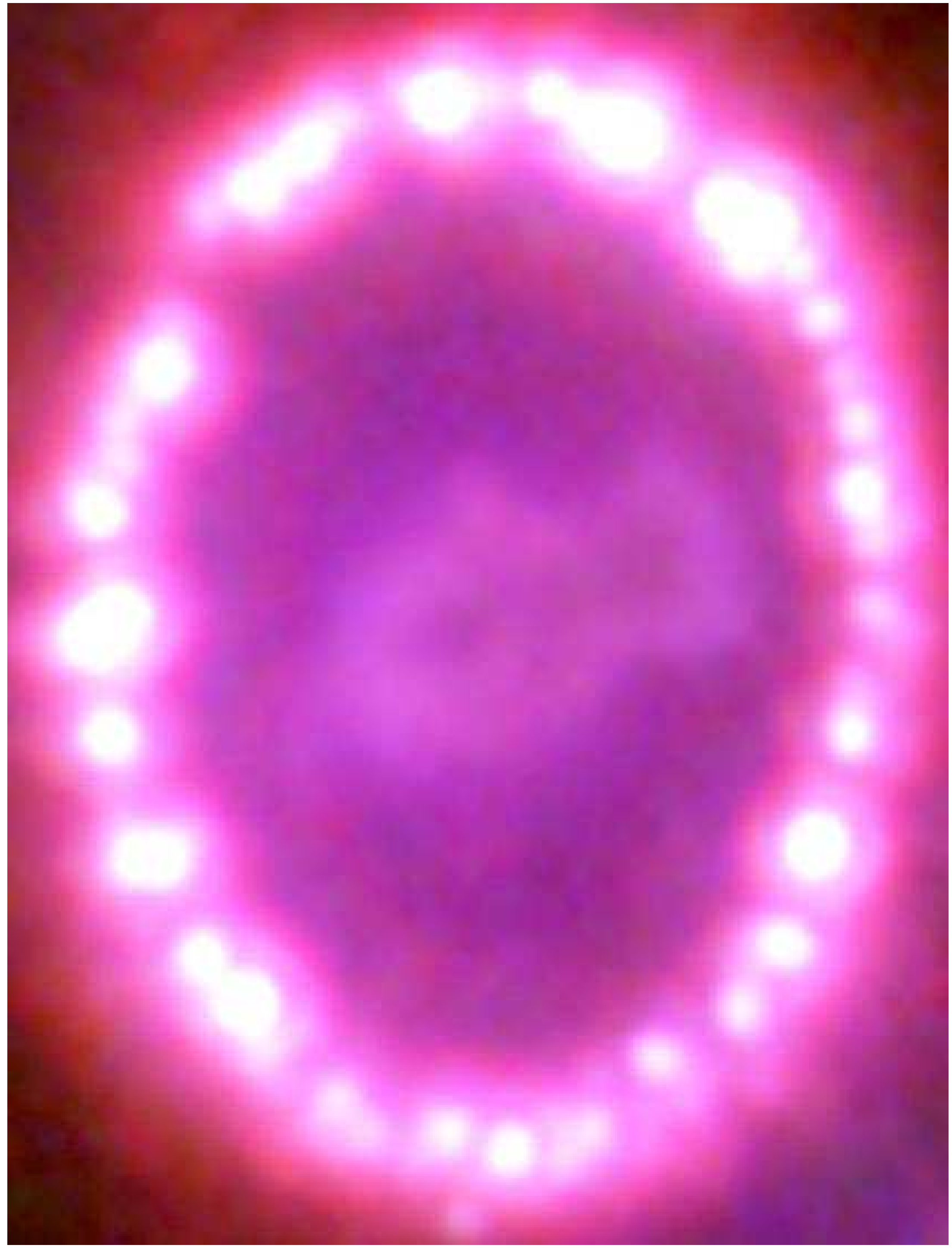


The 180º swing in polarization *across the pulse* is an easy, direct consequence of this model.

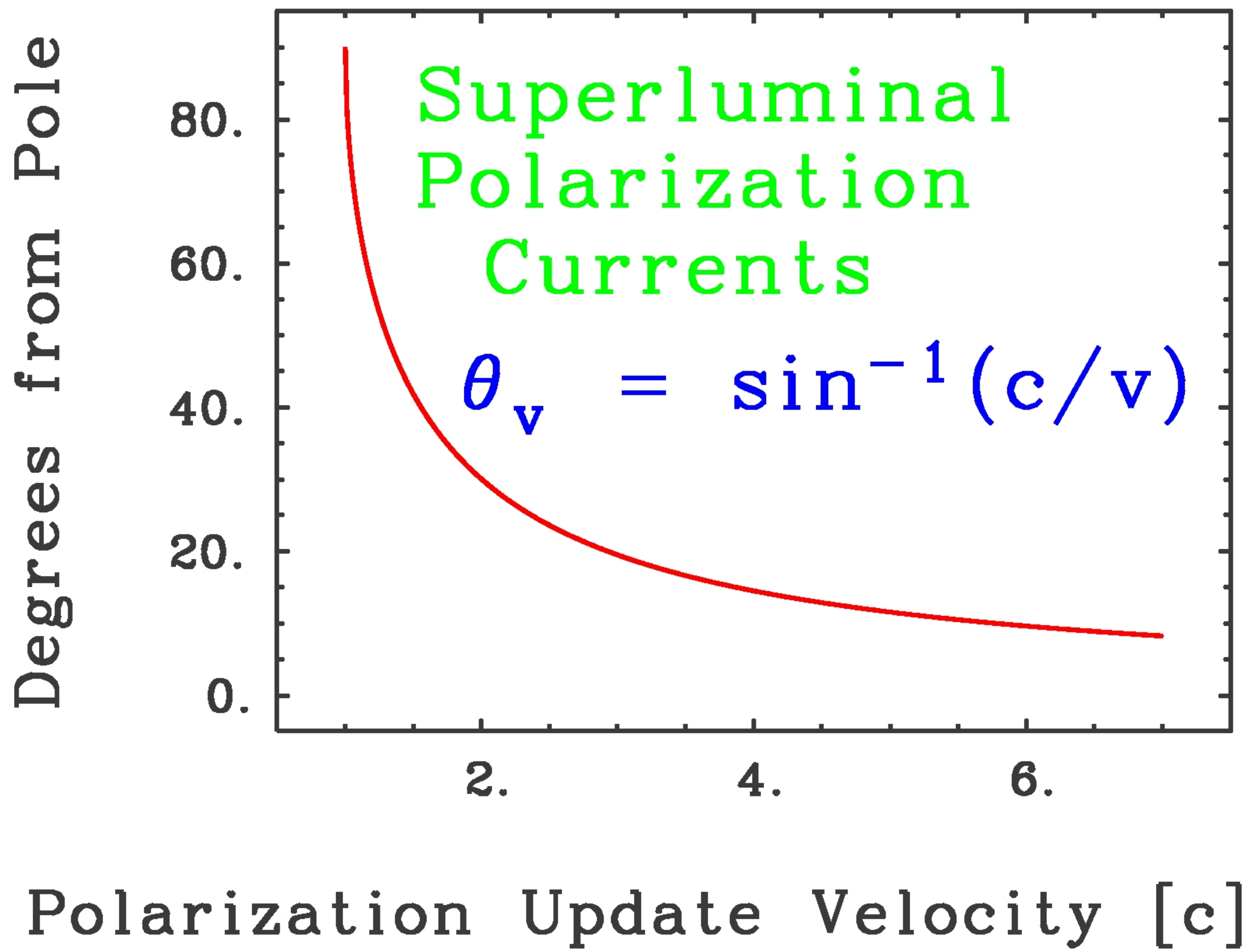




SN 1987A is clearly bipolar. It is thought to have been due to a merger of the cores of two 8-10 $M_{\odot}$ stars. All other SNe measured are also consistent with this bipolarity to some degree. These are 21st century objects, and it is no wonder than λ spectrophotometry alone has not made much progress understanding them.

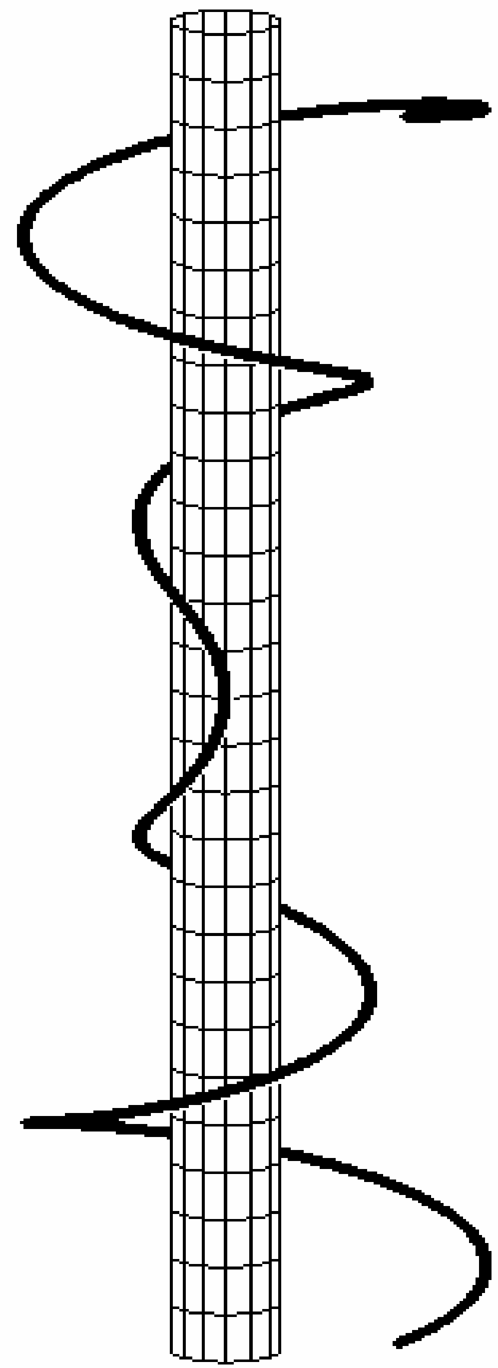


If a pulsar is born within a star, there will be plasma at many light cylinder radii, thus one would expect the pulsed beam to be close to the rotation axis, *right down the gunsight*. This may be the GRB mechanism, and what blows out the poles of SNe.

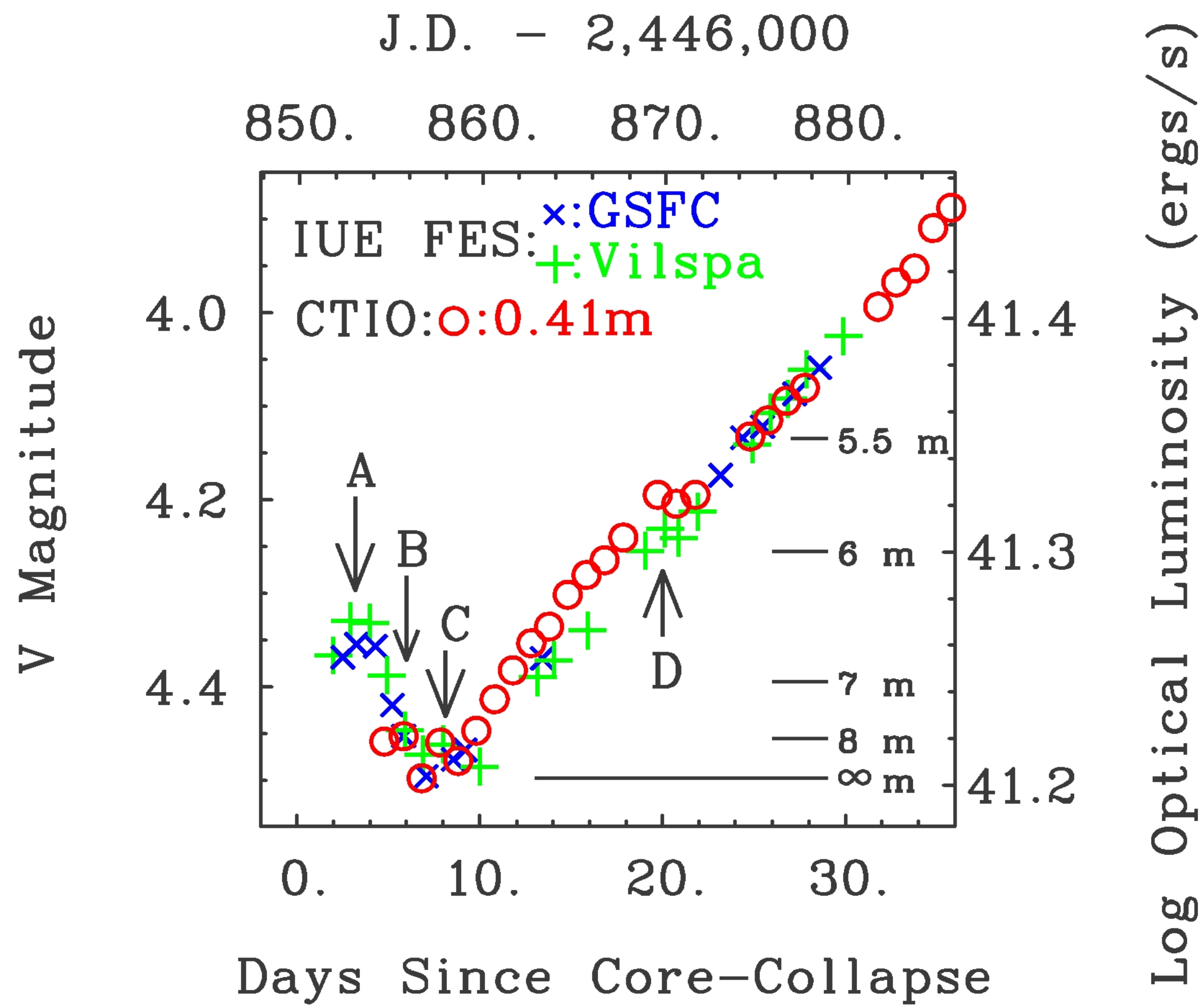


There's a reason why SNe appear as they do, and that reason is what the pulsar does in the first 1-2 months (see further about SN 1987A below). Pulsars are a significant, and unignorable part of the SN process.

The pulsations propagate out on the cone of half angle, θ_v, somewhat like a bedspring. This half angle may have caused the 30º misalignment between 87A's bipolarity and normal to its equatorial ring.



SN 1987A is the Rosetta Stone. Its early light curve indicates an impulsive ejection of particles with a maximum velocity of 0.9 c, penetrating polar ejecta ~11 lt-days away, and ~14 lt-d thick. However, measurements of the “Mystery Spot” (MS) indicate a continued ejection of ~0.5 c particles, not unlike the Crab pulsar movie, for at least a month.



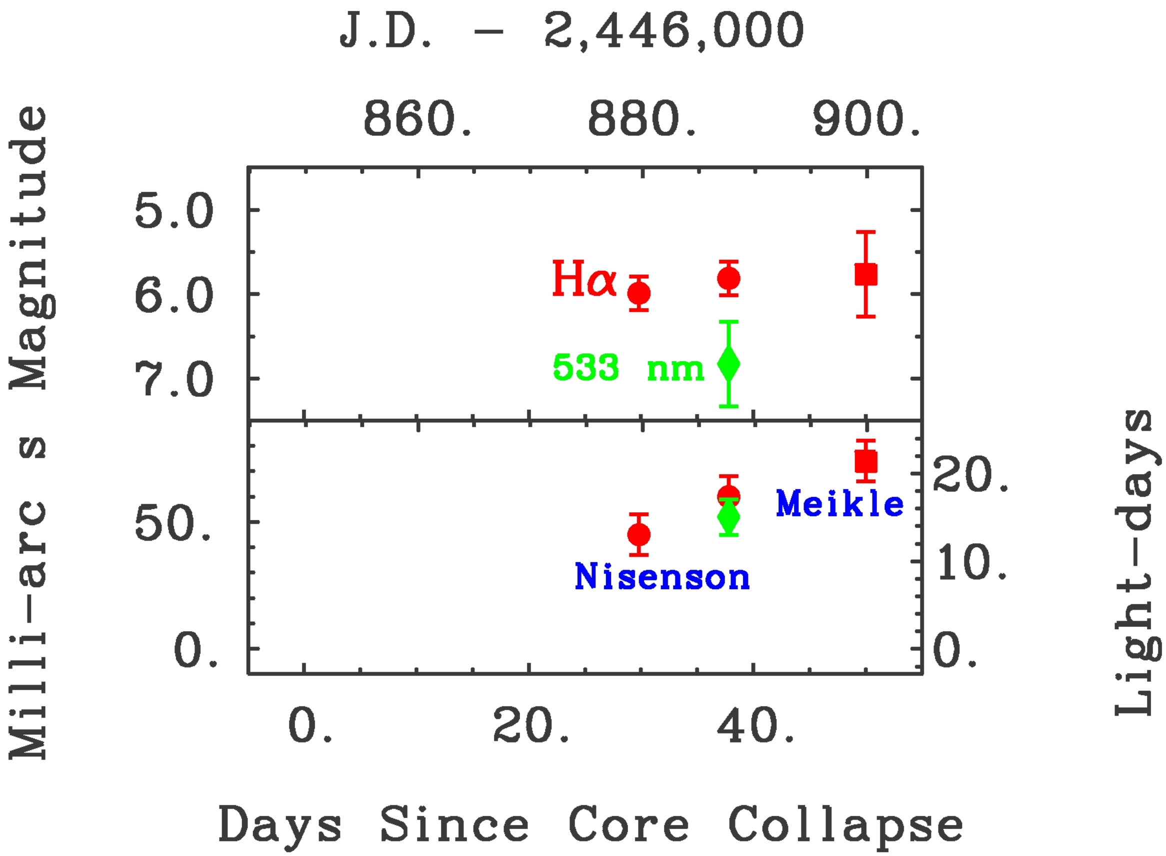
A: Emergence of a luminous jet

B: Cooling (or spreading) of the jet

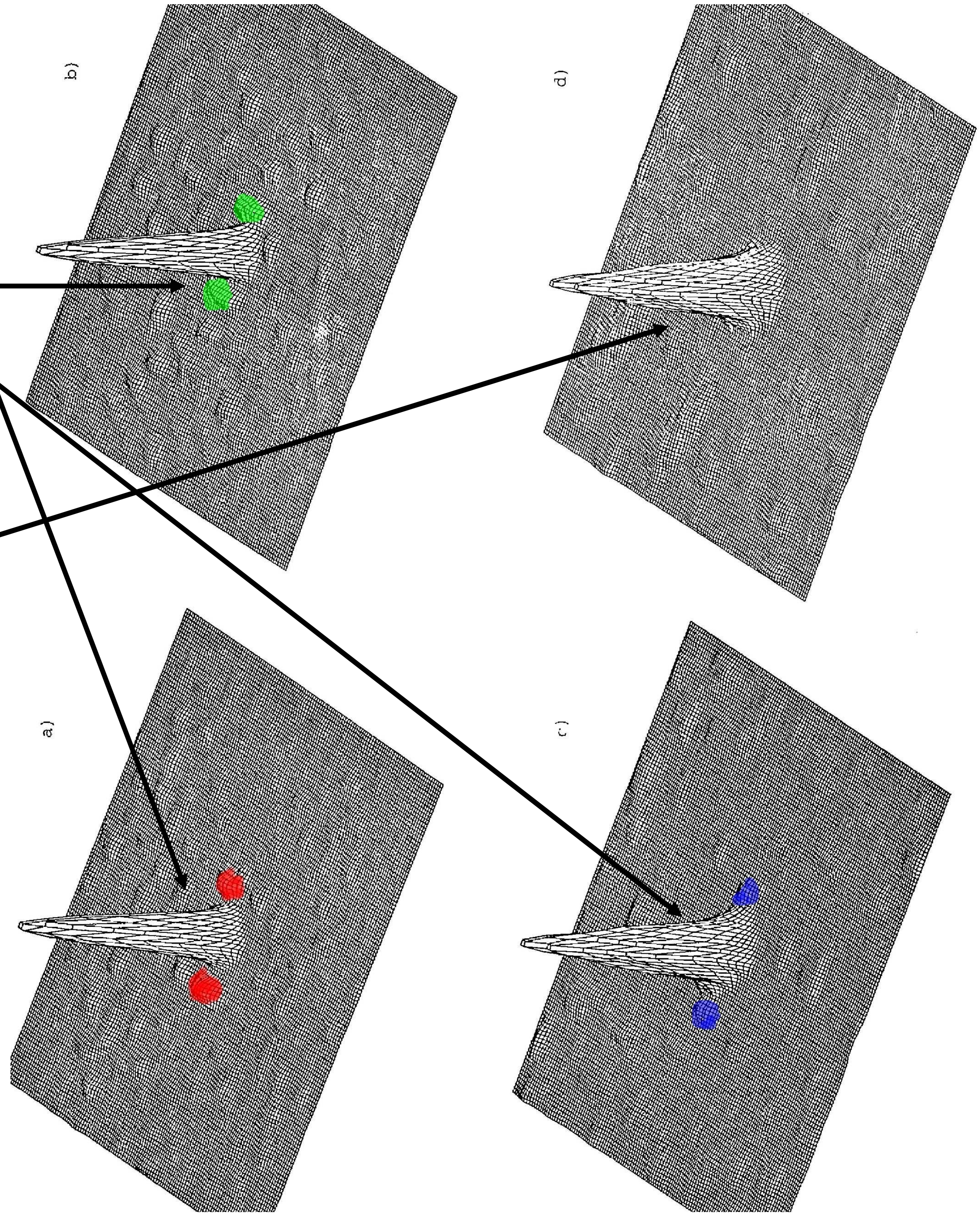
C: UV Superflash hits polar ejecta

D: Jet just through 14 lt-d polar ejecta

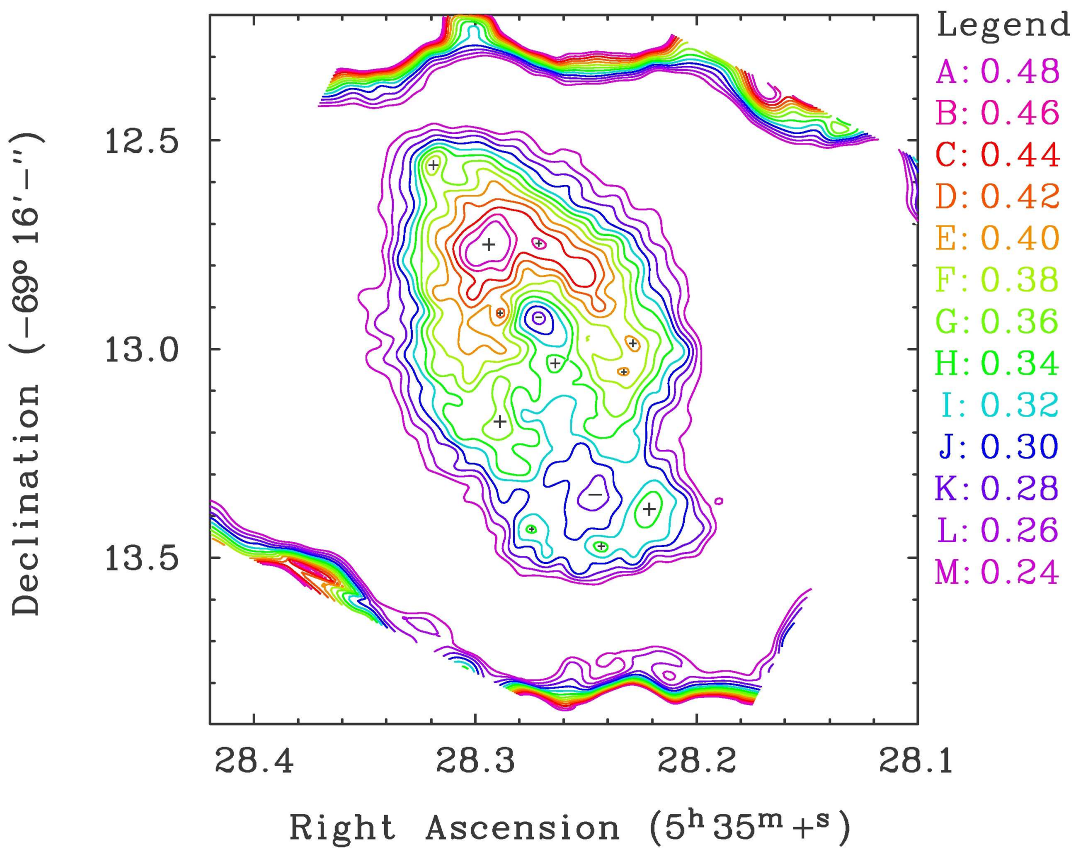
The MS, with up to 8% of 87A's light in Hα, was seen to move from 0.045 arc s at day 30, to 0.060 arc s at day 38, to 0.074 arc s at day 50 (0.5 c – 0.35 c).



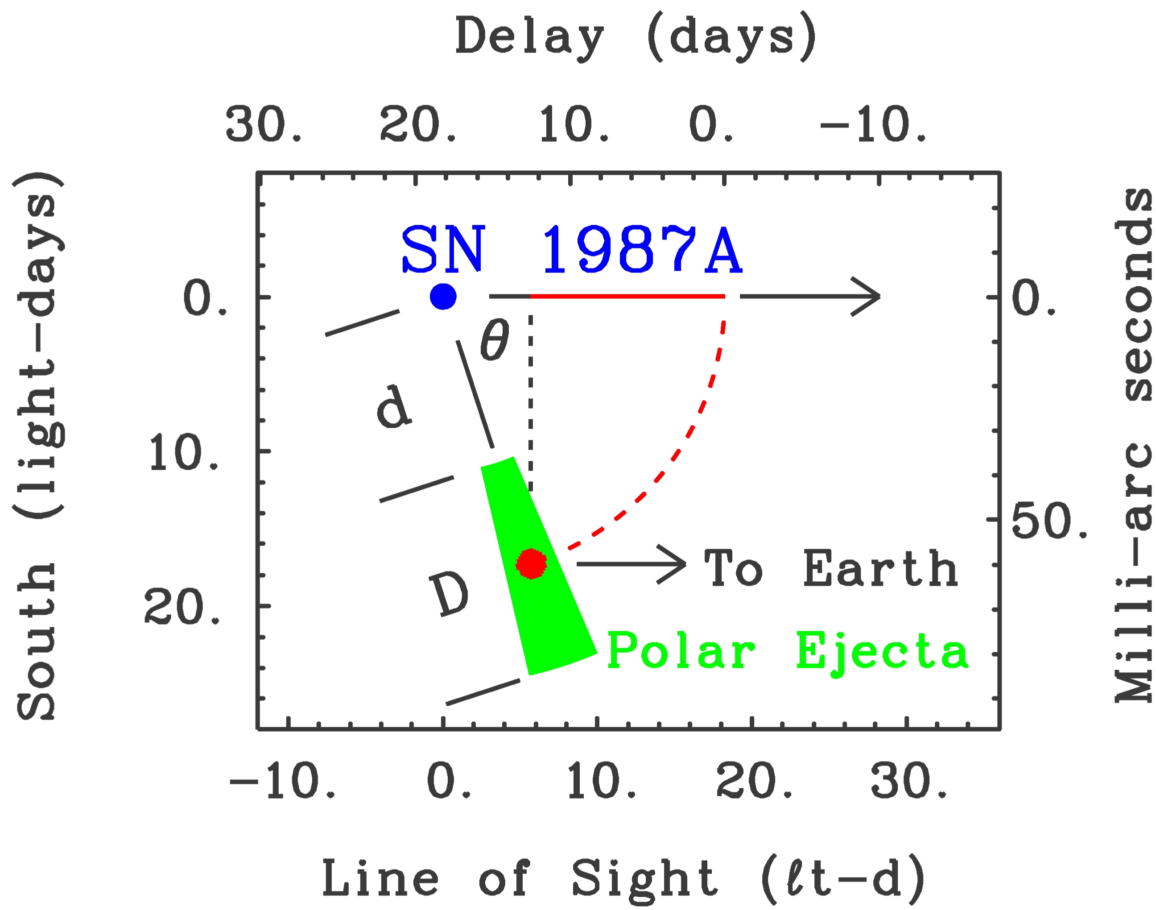
Here are the speckle data for the mystery spot in Hα (lower left), 533 nm (upper left), 450 nm (lower right), and the normal star, ν Doradus (upper right). There is a 180^{o} ambiguity in the display. We could have used speckle starting on day 2!



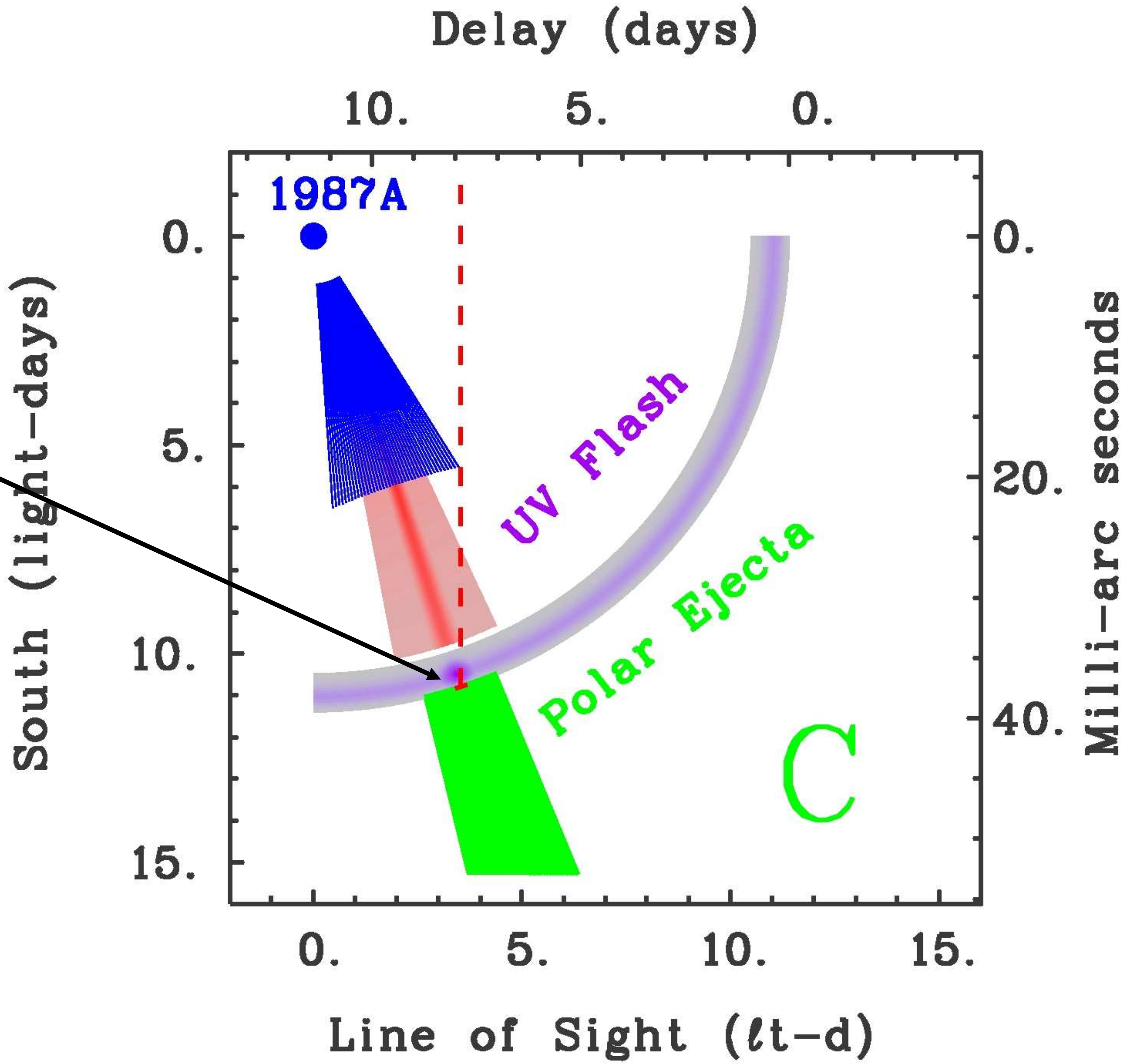
If one does the math, then the angle of the 87A bipolarity to our line of sight is 72^o, and thus the angle between the normal to the plane of the equatorial ring and the bipolarity is 30^o. This is way too much for spin-orbit in the merger, but may indicate plasma only out to 2 LC radii in the SLP model.



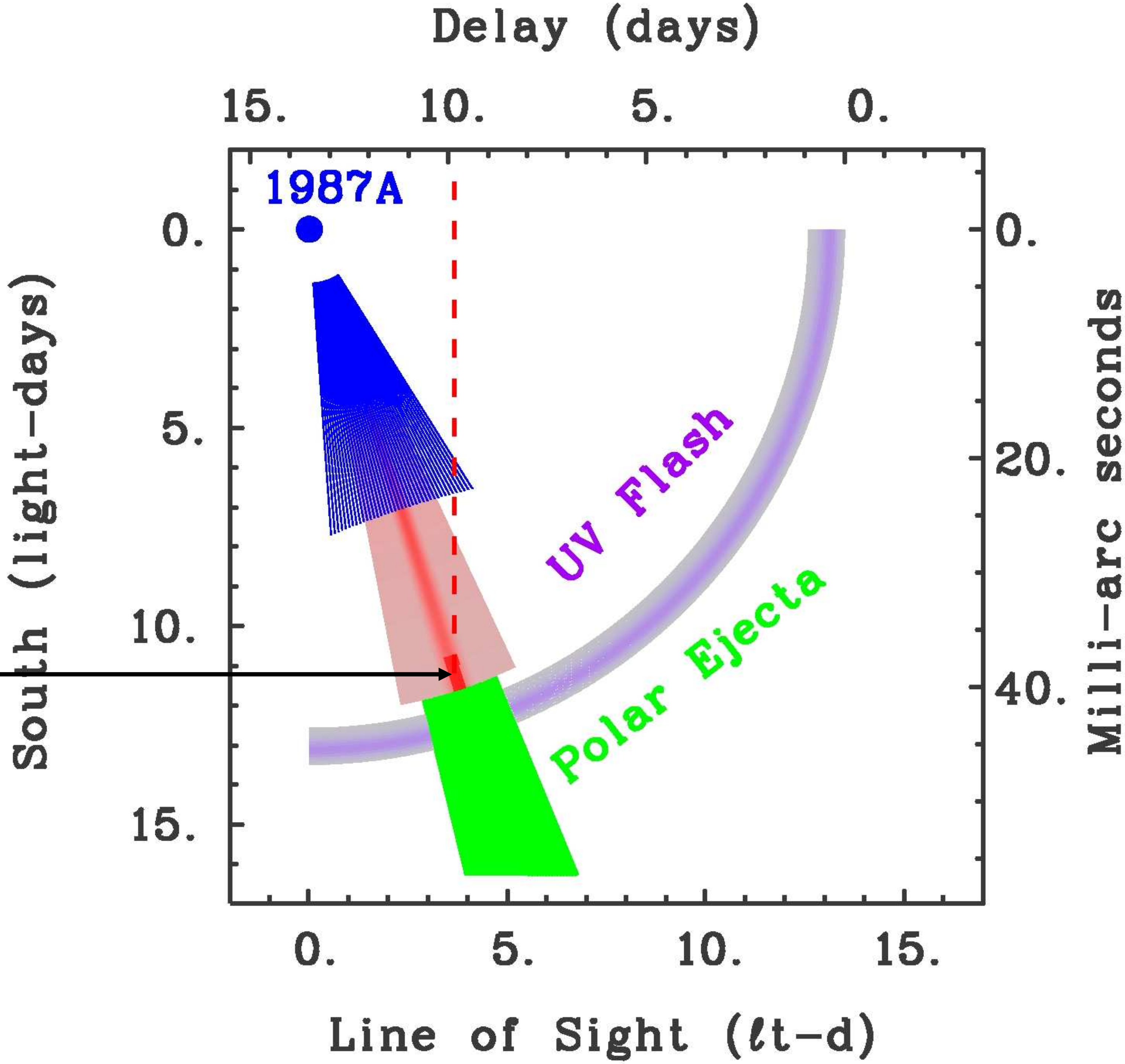
The geometry was more or less as drawn at right. The large angle to the bipolarity may have been the reason that optical pulsations were not seen until years 5.0 – 6.5. The plasma had to thin so that the beam could be more equatorial.



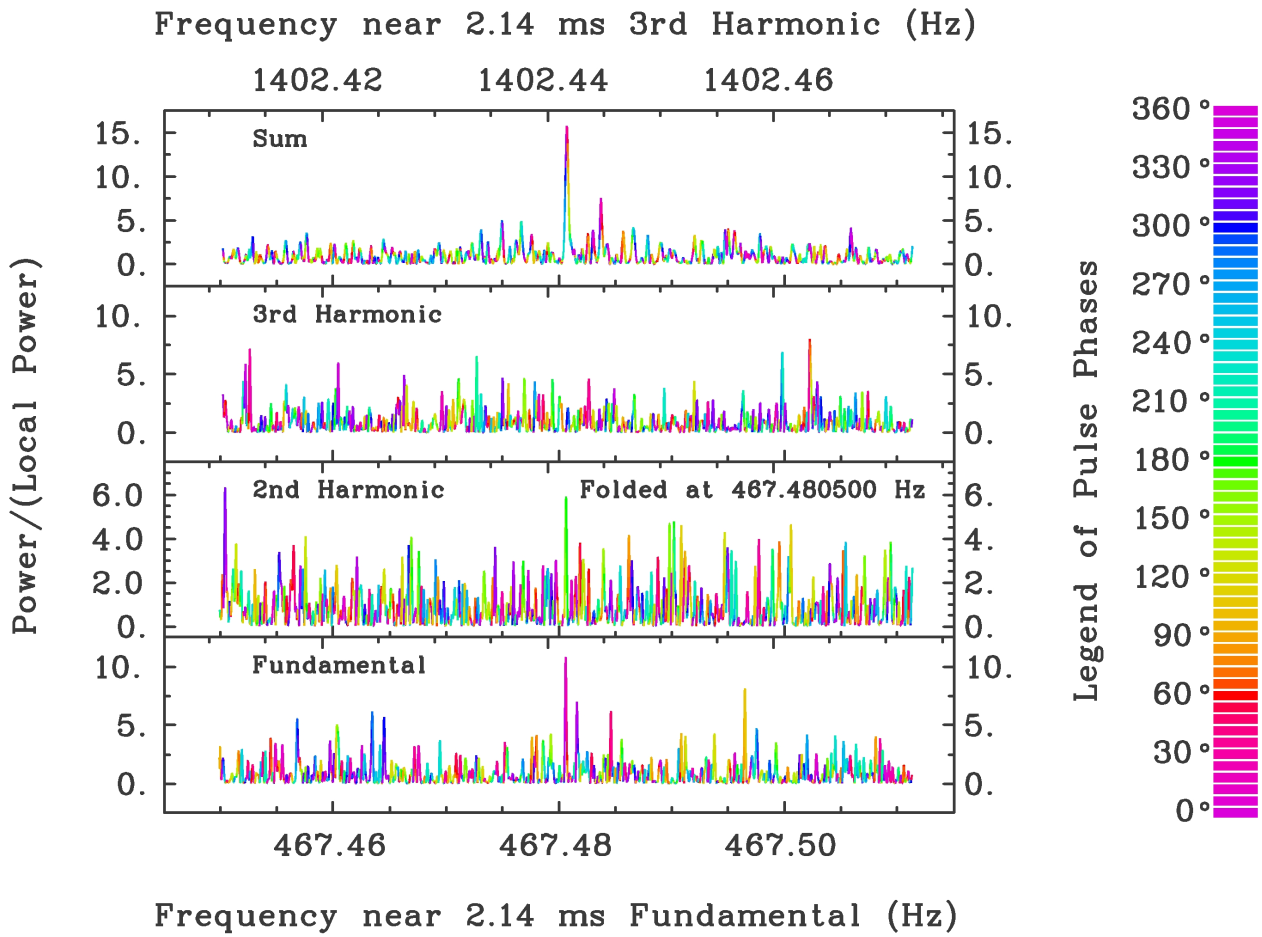
Here, at day 7.8 the UV superflash hits the polar ejecta (tiny red disk) without penetrating very far into it ($\rho \sim 10^7$ cm^{-3}). The collimation factor is $\sim 10^4$.



Here, the particles in the jet penetrate far enough into the polar ejecta by day 9.8 to restore the 87A luminosity to above the day 7.8 level. The collimation factor is still ~10^4.

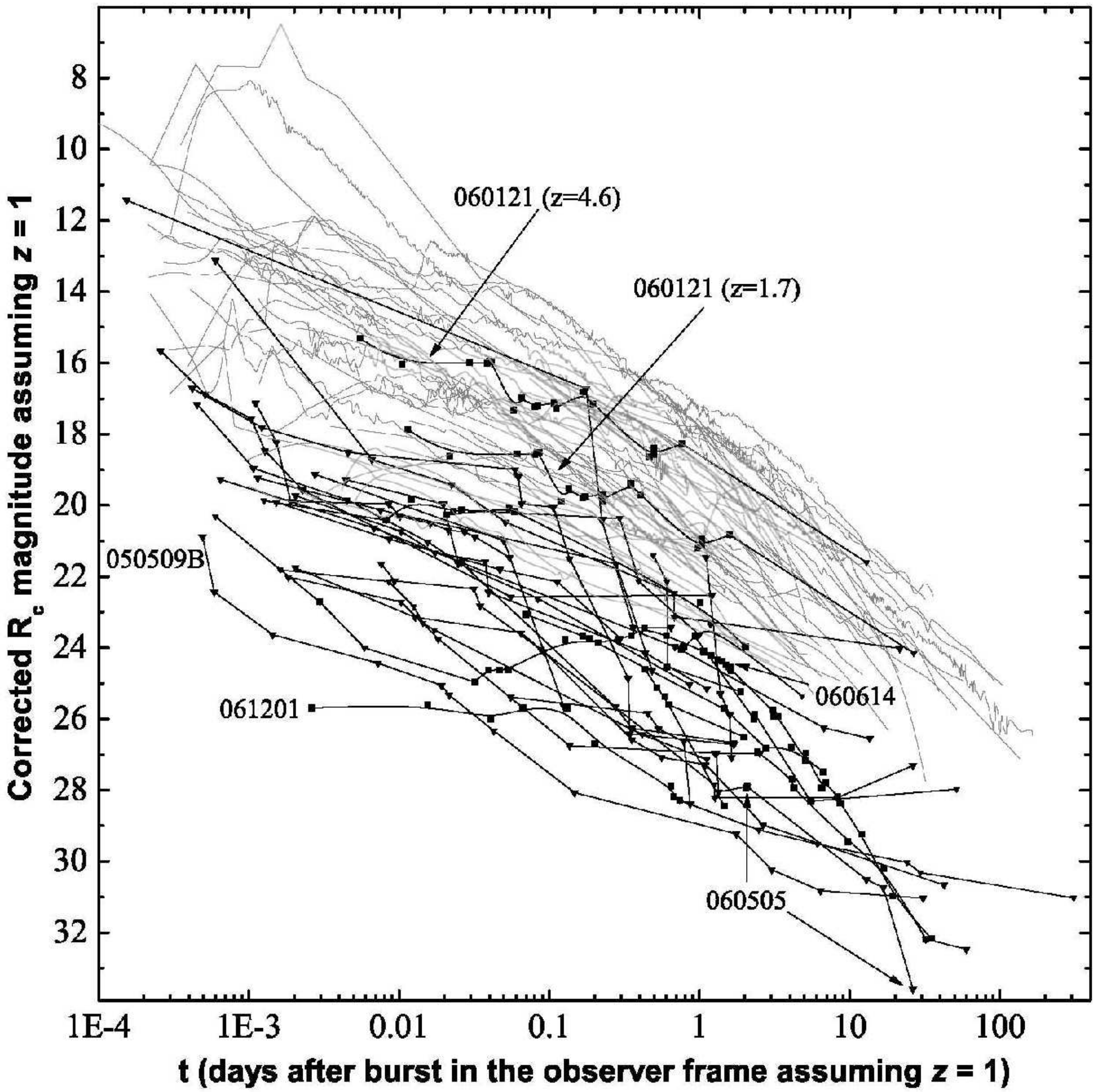


The 2.14 ms signal hammered the Tassies as hard as possible, without being inconsistent with our Wratten 87 magnitude of 21. Their band at their 1-m scope had no U or I.



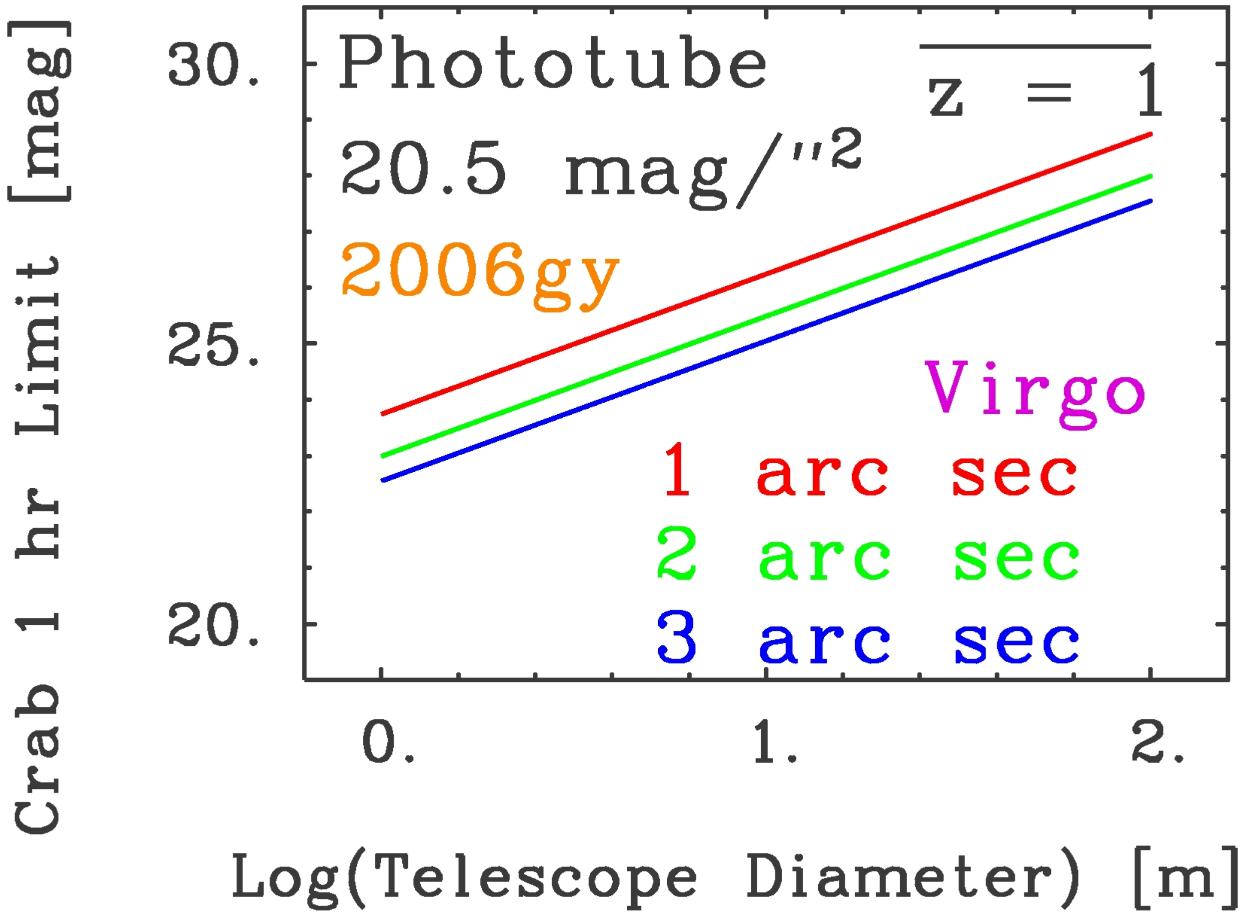
After 1993 August 23, the probability that the 2.14 ms signal was not real, was 10^{-10}. We are not off 8 orders of magnitude! This is real, and the result 99% of the time (Fe catastrophe in massive stars accounting for only 1%). We can get redshifts from these objects (below).

From Kann & Klose, Proc. 2007 Santa Fe GRB Conference. They write: "…, and once again, nearby afterglows were less luminous than more distant ones." Does this sound familiar? Afterglows are pulsars! The free lunch! Are GRBs themselves pulsed? Maybe not.



Pulsars, ALL!

Since pulsars dim only as 1/distance, they are already accessible in the Virgo cluster with Keck-, Gemini-, & Magellan-class telescopes. SN 2006gy with some effort.



z =1 is accessible with synthetic apertures < 0.5”, telescopes with diameters 30 m or more, and photon counting detectors with higher quantum efficiencies.

- We needed fast pulse counting instruments *a few years ago*. Every large, (and even many smaller) telescope(s) on the planet should have the option of fast instruments.
- At least three groups have fast polarimeters and/or photometers: GASP (Galway Automated Stokes Polarimeter), and the South African Large Telescope (Salticam, 0.1 ms). Also Ozzy Sigmund's photon-counting Berkeleycam.
- With GPS, recording fast data has never been easier, and a simple, cheap, photon-counting instrument could be developed.
- The complexity (precession, etc.) of the time signature of an infant neutron star will require support software to ease interpretation, particularly for the casual observer who opts to observe an afterglow in high time resolution. I'll have to write it.

- With the engineering planned for giant telescopes we can detect pulsars out to z ~ 1.
- GRB afterglows may be blazingly bright pulsars, detectable to well beyond (z ~ 6). No Eddington limit applies!
- We can learn about infant neutron stars, GRBs, and SNe, and do cosmology at the same time!
- Because 99% of SNe are mergers, like 87A, these will be standard frequency candles, and we automatically get the redshift, z, as: [(measured pulse period)/(2.14 ms)] - 1.
- Detecting the chirps in GRB afterglows may help LIGO detect GR signatures of SNe.

Pulsars will save Astronomy from itself. (Pulsars Rule the Universe!)

- Sooner or later, the general public will catch on that dark energy and dark matter are just so much pimped-up astroBS (I guarantee you this will happen).
- When that happens, pulsars out to the end of the Universe will be the new (and more lasting) legacy of Astronomy.
- THE END (and the BEGINNING!).

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